

**FY04 Core Support for Shuttle Environmental Assurance (SEA)  
Programs and Projects**

**Final Report  
November 4, 2004**

**NASA Contract: NAS10-03029  
Task Order No. 4**



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## **Executive Summary**

International Trade Bridge Inc. (ITB) supported the Propulsion Systems Engineering and Integration (PSE&I) Office in implementing the Shuttle Environmental Assurance (SEA) Initiative. This work consisted of environmental engineering, technical, business, interface, integration, management and administrative efforts required to develop, plan and integrate environmental activities for NASA's Space Shuttle Program (SSP) and for other related Agency wide environmental programs supported by the SSP PSE&I Office. This final report covers the period November 1, 2003 through October 31, 2004.

Major accomplishments during this period included:

- Tracked and provided comments on Range Safety Issues, including the SSP response to Columbia Accident Investigation Board (CAIB) Observations on public risk associated with Shuttle flight
- Applied the SSP risk matrix approach to SEA Issues
- Supported SEA team collaborative study efforts, including the preparation of draft reports, collection of data, and assessment of environmental health and safety impacts associated with alternate materials
- Prepared briefings for PSE&I Management, the Integrated Logistics Panel, and the Army Environmental Support Office in Process Review
- Prepared comments to Draft Shuttle fly-out/phase out plan
- Completed Final SEA 2003 Annual Report
- Prepared Review Draft of SEA 2004 Mid-year Status Report
- Supported SEA face to face meetings, including planning and preparation of briefings

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## 1 Introduction

The Propulsion Systems Engineering and Integration (PSE&I) Office at Marshall Space Flight Center (MSFC) was tasked to lead the Shuttle Environmental Assurance (SEA) Initiative established by the Space Shuttle Program (SSP) Manager in 2000. SEA is to promote environmental excellence, proactively manage materials obsolescence and optimize associated resources. SEA and the MSFC PSE&I Office also support the SSP in other Shuttle related pollution prevention and environmental issues, including range safety concerns.

SEA works to proactively identify regulatory and other drivers for materials replacement, provides a forum for data sharing and communication to management, and reduces duplication of effort among the shuttle elements through establishment of effective management tools and projects that reduce NASA's environmental risks. PSE&I is working with the NASA Acquisition Pollution Prevention (AP2) Program Office at Kennedy Space Center (KSC) in the proactive identification and integration of pollution prevention, systems safety, and health risk assessments for related NASA programs and initiatives.

International Trade Bridge Inc. (ITB) is supporting the PSE&I Office in implementing the SEA Initiative. This report summarizes ITB core support for the SEA Program and Projects. This work consists of environmental engineering, technical, business, interface, integration, management and administrative efforts required to develop, plan and integrate environmental activities for NASA's SSP and for other related Agency wide environmental programs supported by NASA's Propulsion Systems Engineering and Integration Office.

Ms. Anne Meinhold is accomplishing the ITB, Inc. support to the SEA at Marshall Space Flight Center (MSFC) through Task Order 4, which began on November 1, 2003. This is the final report for this task order and covers the period November 1, 2003 through October 31, 2004.

## 2 Accomplishments

- **Technical Evaluations**

- Completed review of materials and environmental Change Requests (CRs) and Program Requirements Control Board Directives (PRCBD)
- Provided comments on and tracked PRCBD and CR actions addressing Columbia Accident Investigation Board (CAIB) Observations on public risk associated with Shuttle flight
- Tracked range safety panel discussions and briefings concerning possible extension of Solid Rocket Booster (SRB) linear shaped charge
- Provided comment package to Range Safety Panel on Air Force RD3D model and summary of related issues for NASA/SSP
- Provided notes and comments on draft NASA Procedural Requirements (NPR) 8715, Range Safety Program
- Provided comments on MSFC Engineering Directorate report titled "Toxic Gas Exposure Risks Associated with Potential Shuttle Catastrophic Failures"

- **R&D of Materials Replacement Technology and Processes**
  - Tracked JG-PP lead free solder project
  - Collected data on HD2 grease usage
  - Reviewed status of SEA issues
  - Applied SSP risk approach to SEA issues
  - Tracked and supported SEA team collaborative study efforts
  - Developed initial draft of collaborative study reports
  - Developed material on collaborative study risk assessments and environmental, safety and health assessments of currently used products and potential alternatives
  - Worked with elements and contractors to collect usage data for chromated primers, conversion coatings and cadmium plated components
- **SEA Interface Management and Integration Support**
  - Prepared SEA briefing for Integrated Logistics Panel Meeting, June 22, 2004
  - Prepared briefing for Army Environmental Support Office In Process Review, June 3, 2004
- **Administrative**
  - Prepared comments to Draft Shuttle fly-out/phase out plan
  - Completed Final SEA 2003 Annual Report (available on SEA website and server)
  - Prepared Review Draft of SEA 2004 Mid-year Status Report
  - Developed PSE&I Manager Status Briefings (10/03; 1/04)
  - Supported SEA face to face meetings, prepared and delivered presentations, May 5-7, 2004 and October 20-21, 2004.
  - Drafted nomination for United States Environmental Protection Agency Stratospheric Ozone Award for SEA
  - 2004 Group Achievement Award: Shuttle Environmental Assurance Initiative
  - 2004 Group Achievement Award: MSFC Environmental Excellence Team
  - 2004 Group Achievement Award: Shuttle Propulsion Action Center in support of the Columbia investigation

### 3 Cost Summary

- 25.21% of funding expended as of January 31, 2004
- 47.52% of funding expended as of April 30, 2004
- 75% of funding expended as of July 31, 2004
- 100% of funding expended as of October 31, 2004

### 4 Technical Evaluations

#### Change Requests

In preparation for return to flight, the PSE&I Office is reviewing and tracking formal CRs and PRCBDs that may affect more than one Shuttle element. ITB supported PSE&I in reviewing, commenting on and tracking the progress of CRs and PRCBDs that are related to SEA issues and other environmental and range safety concerns.

## Range Safety Panel

ITB supported PSE&I in tracking work by the Range Safety Panel related to range safety issues. Issues of particular concern include a series of actions and PRCB briefings related to range safety issues identified as findings and observations by the CAIB report. ITB provided comments on PRCBD S064026 and continued to actively track these CRs and PRCBDs through participation in PRCB meetings and review of documents. ITB summarized these CRs and how they address CAIB observations (Appendix B1). ITB's major concern with the approach taken by the Range Safety Panel is that range safety issues are not being addressed in an integrated way. Estimates of risk and decisions concerning risk mitigation (such as alternate landing sites, changes in flight rules) should be made with all available information and by weighing costs and benefits.

MSFC PSE&I is supporting the Range Safety Panel in its efforts to review the available modeling and assumptions associated with a catastrophic loss of the Shuttle during launch. The Air Force is developing a new model (RD3D) that will be used to predict human health effects associated with the loss of a Shuttle. ITB prepared a comment package for transmittal to the Range Safety Panel Lead with comments concerning the Air Force RD3D model (Appendix B2). The model appears to be appropriate for use in predicting the consequences of an accident, but has not been adequately documented or peer reviewed. In addition, the model will not be ready for implementation for several years. ITB will continue to support PSE&I and the Range Safety Panel in evaluating the Air Force model.

The Range Safety Panel is also assessing the feasibility and potential risk reduction that would be achieved by extending the linear shaped charge on the SRB down to the aft segment. Most of the predicted risk associated with debris following a catastrophic accident on ascent comes from the breakup of a free flying SRB over a populated area. The linear shaped charge (LSC) used to detonate the SRB in this situation does not extend to the aft segment of the booster. The Air Force model used to assess risk associated with a catastrophic accident on launch assumes that the aft segment will impact land intact, and that the fuel remaining will detonate causing a large debris impact. Data from Challenger suggest that this is possible, and RSRM (Reuseable Solid Rocket Motor) does not have data suggesting otherwise. The Range Safety Panel has estimated that extending the LSC to the aft segment would reduce the  $E_c$  (expected number of casualties/deaths) by about a factor of 7.

ITB also provided notes and formal comments on a Draft NPR under development by HQ (NPR 8715, Range Safety Program) (Appendix B3). This NPR would have required development of a program level risk management plan. It required compliance with Air Force risk criteria and allowed for tailoring to meet criteria. This NPR was withdrawn and will probably not be available before return to flight.

## Review of MSFC Engineering Directorate Toxic Cloud Report

ITB reviewed and provided comments on a report prepared by the MSFC Engineering Directorate entitled "Toxic Gas Exposure Risks Associated with Potential Shuttle Catastrophic Failures" (Appendix B4). This report suggests that the model used by the Air Force to predict potential human health effects associated with a catastrophic Shuttle loss on launch is likely to under-predict the concentrations of HCl near the launch site. The report makes some valid

points concerning the currently used model (REEDM), but does not correctly characterize the current situation at KSC in terms of potential exposures and does not adequately discuss the basis for the criteria used in assessing risk.

## 5 R&D of SSP Materials Replacement Technology and Processes

### SEA Issues

The SEA team is currently working 18 issues. This past year SEA closed one issue (3M Tapes), began work on a new issue (Brominated Flame Retardants) and facilitated mitigation of one issue by other SSP groups (Neoflon/Kel F). Four of these issues are being addressed in collaborative studies (hexavalent chromium in primers, hexavalent chromium in conversion coatings, cadmium in plating applications, HCFC 141b) and ITB has major responsibility for facilitating this work. The current status of these issues is summarized in the Draft Mid-Year Status Report (Appendix E1).

### **SEA Issues**

HCFC 141b Blowing Agent
1,1,1 Trichloroethane Elimination (Orbiter use)
1,1,1 Trichloroethane Elimination (RSRM use)
Cadmium Replacement in Plating Applications
Hexavalent Chromium Replacement in Primers
Hexavalent Chromium Replacement in Conversion Coatings
Chemical Paint Stripper Alternatives
Alternate Dry-Film Lubricant
High volatile Organic Carbon Coatings
Hypalon Paint
Lead-Free Electronics
Hexavalent Chromium in Alkaline Cleaners
Hazardous Air Pollutant inks
Methyl Ethyl Ketone Replacement
Cleaning and Verification Solvents
Perfluoroalkyl Sulfonates
Brominated Flame Retardants
Neoflon™/Kel F

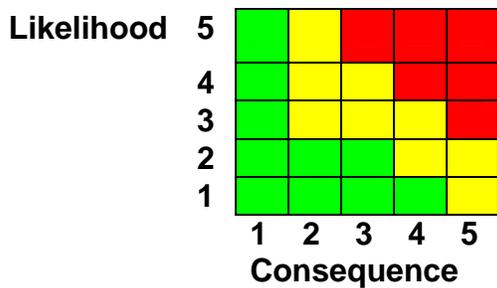
ITB has major responsibility in tracking the lead-free solder issue for SEA. SEA continues to track the potential impact of the industry trend toward lead-free solders. Orbiter issued a letter to its suppliers emphasizing that lead-free products are still not approved for use. SEA is participating in the JG-PP project to evaluate lead-free solders and is being supported by the MSFC Avionics Department. The AP2 Office is managing this project and periodically briefs the SEA Team on its status. Completed test vehicles, both manufactured and reworked were shipped to the various testing locations in July. The wiring and test set up is underway, and the testing phase is scheduled to run from August through November 2004. The MSFC Avionics support team is working with NASA Headquarters to address this issue for the Agency.

ITB has also supported SEA in addressing the obsolescence of HD2 Conoco Grease. ITB developed a formal action request to collect data from each element estimating the amount of HD2 grease that will be required through the end of the program. ATK Thiokol is planning a lifetime buy of the natural sulfonate used to manufacture the HD2 grease, and plans to acquire enough of the material to satisfy the needs of all the Shuttle elements. Orbiter expects to use about 5 gallons through 2012, and SRB is planning to qualify the replacement material suggested by the manufacturer. ET, SSME and Suits do not use the material. Ground Support

at KSC will need about (TBD) of the material through the life of the program. SEA will help coordinate Orbiter and KSC procuring needed material from ATK.

SEA Issue Management and Risk Assessment

Risks associated with SEA issues are assessed using the Space Shuttle Program risk matrix. Risks to the SSP associated with the loss of a material or environmental, health and safety concerns are assessed in terms of both probability and impact. The risk matrix plots the likelihood that an issue will affect the SSP – from “unlikely to occur” (1) to “may be expected to occur” (5) – against the consequence of the issue if it does occur – from “no safety and health plan violation” or “no increase in processing or maintenance time “ (1) to “potential for permanent injury or death” or “ loss of maintenance capability impacting critical processes or essential elements “ (5). Issues that fall in the red zone are those that present high risks to the program, those in yellow present medium risks, and those in the green zone present low risks.



Baseline Risks are those risks to the program assuming no mitigation of the issue. SEA has considered several approaches to the assessment of current safety / supportability risk that would capture both the technical risk involved in finding a replacement for a material as well as the extent to which a mitigation plan has been developed and funded.

The SSP is planning to implement a standard risk assessment and reporting process being developed by S&MA. This process uses the SSP risk matrix (which will be modified in the Fall of 2004) and a database/reporting software to assess SSP wide issues and report high program risks directly to Level 2 management.

The SEA team will decide whether SEA issues should be included in this data base. In most cases it is probably more appropriate for each element affected by an issue to decide whether and how to include the issue in the risk data base, since the final risk and mitigation of the issue is owned by the element, even if collaborative work with other elements is part of the mitigation plan. The data base is also currently more geared to short term return-to-flight issues rather than the longer term issues being addressed by SEA.

ITB developed draft current safety/supportability risks for the SEA issues using the current SSP risk matrix. These current risks have been entered into the SSP risk database, but the issues have been coded as “concerns” which prevents them from being accessed by other SSP organizations or directly elevated to Level 2 management. These current risks will be reviewed by the SEA team.

Baseline and Draft Current Supportability/Safety Risk Assessment for SEA Issues\*

<b>ISSUE</b>	<b>BASELINE (Supportability or Safety) (PROBABILITY x CONSEQUENCE)</b>	<b>CURRENT (Supportability or Safety) (PROBABILITY x CONSEQUENCE)</b>
HCFC 141b Blowing Agent	HIGH (5 x 5)	MEDIUM (1 x 5)
1,1,1 Trichloroethane Elimination (Orbiter use)	HIGH (5 x 5)	MEDIUM (1 x 5)
1,1,1 Trichloroethane Elimination (RSRM use)	HIGH (5 x 5)	MEDIUM (1 x 5)
Cadmium Replacement in Plating Applications	MEDIUM (3 x 4)	MEDIUM (3 x 4)
Hexavalent Chromium Replacement in Primers	MEDIUM (3 x 4)	MEDIUM (3 x 4)
Hexavalent Chromium Replacement in Conversion Coatings	MEDIUM (3 x 4)	MEDIUM (3 x 4)
Chemical Paint Stripper Alternatives	MEDIUM (3 x 3)	LOW (1 x 3)
Alternate Dry-Film Lubricant	MEDIUM (3 x 4)	LOW (1 x 4)
High volatile Organic Carbon Coatings	MEDIUM (3 x 4)	LOW (1 x 4)
Hypalon Paint	MEDIUM (3 x 3)	LOW (1 x 3)
Lead-Free Electronics	MEDIUM (3 x 4)	MEDIUM (2 x 4)
Hexavalent Chromium in Alkaline Cleaners	LOW (2 x 2)	LOW (2 x 2)
Hazardous Air Pollutant inks	LOW (2 x 2)	LOW (2 x 2)
Methyl Ethyl Ketone Replacement	LOW (2 x 2)	LOW (2 x 2)
Cleaning and Verification Solvents	LOW (2 x 2)	LOW (2 x 2)
Perfluoroalkyl Sulfonates	LOW (2 x 2)	LOW (2 x 2)
Brominated Flame Retardants	TBD	TBD

\*Based on SSP Risk Matrix, baseline risk is risk without mitigation

### Collaborative Studies

SEA initiated scoping studies to provide recommendations to the SSP concerning the potential benefits of future, multi-element collaborative replacement efforts for four materials: HCFC 141b in TPS, hexavalent chromium in epoxy primers, hexavalent chromium in conversion coatings, and cadmium in plating applications. In these studies, the affected hardware elements will (1) identify common performance requirements for replacement materials; (2) summarize work done by other agencies; (3) identify potential replacements; (4) make recommendations to the Program; and (5) develop a coordinated mitigation plan.

The Conversion coating study was initiated in October 2003. The primer and cadmium studies were initiated in December 2003. A recommendation for further Program action and, if appropriate, a coordinated mitigation plan for these three collaborative efforts is planned for completion in CY04. The SEA Team is planning to develop briefings and a request for funds to support initial collaborative test plans that will go to the Program in early 2005. Collaborative

work on the replacement of HCFC-141b will depend on return-to-flight activities and priorities.

ITB is supporting SEA in managing and facilitating these collaborative studies, and developed an annotated outline for the collaborative study reports. ITB will be responsible for the risk assessment and environmental health and safety screening of currently used and alternative materials, and initiated that effort. The ITB staff in the AP2 Office is working closely with SEA in identifying requirements for replacement materials as well as identifying and summarizing work done by other agencies. Patti Lewis (ITB/AP2) provided detailed summaries of work being done by other agencies in support of these studies. ITB has also worked to collect usage data for chromated primers, chromated conversion coatings and cadmium plated components to support a risk assessment and environmental health and safety analysis. ITB also prepared an initial draft of the chromated conversion coating and chromated primer report to support Lockheed Martin in preparing a report to satisfy their Special Development Study requirement by September 2004. With input from Lockheed Martin, Boeing, United Space Alliance and the NASA AP2 Office, ITB prepared an initial draft of the hexavalent chromium collaborative study reports (Appendix C1). ITB also prepared a draft schedule for these reports to facilitate the completion of the report, briefings and change requests (Appendix C2).

## **6 SEA Interface Management and Integration Support**

ITB is working to develop interfaces with other NASA organizations and agencies to leverage information, aid in technology transfer, and optimize resources for the SSP and other agencies. Ms. Meinhold continued to work with the AP2 Office to share information generated by SEA and to pass on Pollution Prevention requests from the Clean Air Act Working Group and other NASA organizations. The NASA AP2 Office is providing support to the SEA in its implementation of the Collaborative Studies work and has been providing useful information and contacts to the group. ITB also continues to engage the MSFC Environmental Office and the Engineering Directorate in SEA activities and the SEA collaborative studies. ITB is also working to engage the Air Force Space Command at Peterson Air Force Base in working with SEA. Mr. Dean Dunn with Air Force Space Command is interested in collaborating with NASA and Shuttle on mitigation projects, and plans to attend SEA teleconferences and face to face meetings.

ITB developed a briefing for the Integrated Logistics Panel meeting held June 22, 2004 (Appendix D1). ITB also prepared a SEA briefing and attended a meeting of the In Process Review hosted by Redstone Arsenal and held in Huntsville June 3, 2004 (Appendix D2).

ITB attended the 2004 NASA Environmental Conference, May 24-27 in Albuquerque, New Mexico. A major emphasis of the conference was sustainability, and several presentations focused on how NASA centers can work toward this goal. NASA Code JE announced plans to establish a NASA Center of Excellence focused on sustainability.

ITB prepared give-aways and presentation material and coordinated with the MSFC Environmental Office in supporting Earth Day activities at MSFC April 15.

## **7 Administrative Support**

### Shuttle Fly-out/Phase-Out Plan

The SSP is beginning to plan for the eventual decommissioning of the Shuttle. This effort will require an assessment of personnel, assets and environmental issues. ITB reviewed the initial draft of the Fly-out/ Phase-out plan, and suggested more specific language outlining the efforts that will be required to identify and plan for environmental issues associated with an SSP Phase-out. These include issues associated with the disposition of facilities, hardware and materials, environmental remediation, identification of risk management options and associated cost and schedule estimates and the identification of liability issues and compliance responsibilities.

### Annual Report

ITB developed the initial review draft for the SEA 2003 Annual report. This draft was completed on January 30, 2004. ITB addressed comments by the SEA team and sent out a final review draft in March. ITB made changes to this draft and prepared photographs for inclusion in the report. This draft was completed April 30. ITB worked with MSFC graphics to prepare the layout of the document. The report was finalized in June 2004 and is available on the SEA website and server.

### Mid-year Status Report

ITB drafted the initial review draft for the SEA 2004 Mid-year status report (Appendix E1). This draft was completed on October 1, 2004. ITB will address comments by the SEA team and complete the final report.

### Management Update

ITB developed briefings to status PSE&I Management (10/03; 1/04; Appendix E2). ITB also developed a briefing for PSE&I Management and Engineers on materials issues identified by SEA. These included PCTFE, Hydrogen Embrittlement, HD2 grease and Brominated Flame Retardants (Appendix E3). ITB also updated a summary table describing the status of the SEA issues for PSE&I Management (Appendix E4).

### Meetings

ITB supported the planning for the SEA face to face meeting held at the USA NSLD Building in Cape Canaveral, May 4-6. ITB supported development of meeting agendas, and coordinated the purchase of give-aways and other team building projects. ITB also developed and presented briefings on Issue Management and SEA Future Planning (Appendix E5)

ITB also developed briefings for the SEA face to face meeting held at the USA Discovery Drive Building in Huntsville, October 20-21 (Appendix E6).

## Awards

ITB was included in three Marshall Space Flight Center Group Achievement Awards this spring.

- Member of the MSFC Environmental Excellence Team
- Member of the Shuttle Environmental Assurance Team
- Member of the Shuttle Propulsion Action Center in support of the Columbia investigation

ITB drafted the documentation for nomination of SEA for a United States Environmental Protection Agency Stratospheric Ozone Award (Appendix E7). SEA won this award and Ms. Meinhold attended the award ceremony in Washington, D.C. on April 14.

## **8 Technical Products and Deliverables**

Technical reports and deliverables completed include:

- Comments on PRCBD and CR actions addressing CAIB Observations on public risk associated with Shuttle flight (S064026) (Appendix B1)
- Comment package to Range Safety Panel on Air Force Model RD3D and summary of related issues for NASA/SSP (Appendix B2)
- Comments on 8715 Range Safety (Appendix B3)
- Technical comments on Draft document “ Toxic Gas Exposure Risks Associated with Potential Shuttle Catastrophic Failures” (Appendix B4)
- Collaborative Study Reports Initial Drafts (Appendix C1)
- Collaborative Study Schedule (Appendix C2)
- Integrated Logistics Panel briefing, June 22, 2004 (Appendix D1)
- Army Environmental Support Office In Process Review Briefing, June 3, 2004 (Appendix D2)
- Final 2003 Annual Report (available on SEA website and server)
- Draft Mid-year Status Report (Appendix E1)
- Management Updates 10/03; 1/04 (Appendix E2)
- Management Materials Issues Update (Appendix E3)
- Issue Status Table (Appendix E4)
- Briefing materials: SEA May 2004 face to face (Appendix E5)
- Briefing materials: SEA October 2004 face to face (Appendix E6)
- USEPA Award Summary (Appendix E7)

## 9 Recommendations

NASA is currently planning to phase-out the Shuttle in 2010 or when the Space Station is complete. This could be as late as 2013. This shift from 2020 to 2010 changes the priorities of the program, and should also change SEA's priorities.

Our current focus on long-term replacement projects will need to change to address the reality of a 2010 or 2013 phase-out date. Justification for the replacement of materials based on obsolescence will have to demonstrate an immediate risk and a short term payback. Materials replacement can also be justified if impacts to other programs and the new crew exploration vehicle are considered. SEA should actively work to influence and support other NASA programs that will be faced with obsolescence issues that can be avoided with the testing and replacement of materials such as chromium and cadmium now.

SEA should also take an active role in the phase-out planning for Shuttle, particularly in addressing the environmental issues that will drive the process. The Shuttle program will have to address issues associated with NASA materials and environmental contamination at contractor sites and identification of assets that will need disposal or transfer to other NASA programs or to other agencies. The phase-down team will need to provide environmental planning, studies, designs, integration, regulatory coordination and recommendations concerning disposition of facilities, materials and other SSP assets. These are all areas that the SEA team can support.

The NASA Headquarters Environmental Office has a new focus on sustainability. SEA should play an active role in clarifying this approach and its implications for NASA, for the SSP, and for new programs and vehicles.